

Appin. No. 10/810,952
Amdt. dated: March 29, 2006
Reply to Office Action dated: December 29, 2005

Remarks/Arguments

These remarks are in response to the Office Action dated December 29, 2005. This reply is timely filed. At the time of the Office Action, claims 1-26 were pending in the application. All pending claims have been rejected under 35 U.S.C. 103(a). The rejections are set out in more detail below.

I. Brief Review of Applicants' Invention

Prior to addressing the Examiner's rejections on the art, a brief review of Applicants' invention is appropriate. The invention relates to a toroidal transformer and methods of forming a toroidal transformer in a ceramic substrate. The toroidal transformer is formed of a toroidal transformer core integrally formed with the ceramic substrate. A plurality of turns of a conductive coil are disposed around the ceramic toroidal core. The method include the steps of forming a plurality of conductive coils that comprise one or more turns about an unfired ceramic toroidal core region defined within a ceramic substrate. The method also includes the step of co-firing together, as a single unit, the unfired ceramic toroidal core region, the unfired ceramic substrate, and the conductive coil to form an integral ceramic substrate structure with the conductive coil at least partially embedded therein.

II. Claim Rejections Under 35 U.S.C. §103(a)

a. Claims 1, 2, 8, 10, 18, 19, and 23

Claims 1, 2, 8, 10, 18, 19, and 23 have been rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Published Application No. 2004/0124961 to Aoyagi ("Aoyagi") in view of U.S. Patent No. 6,820,321 to Harding ("Harding").

Aoyagi discloses a printed inductor having a spiral coil formed outside a linear cavity. The invention includes an insulating ceramic (LTCC) substrate with the linear cavity extending in a direction orthogonal to that of the thickness of the insulating ceramic substrate. The cavity is formed using conventional machining techniques, either before or after the substrate is fired. (page 2, ¶ 24). Aoyagi shows that a transverse bore can be drilled in the thickness of the substrate material to form the

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cavity. The cavity is backfilled with ferromagnetic metal material, such as ferrite (page 2, ¶ 29). Also, printed wiring lines are disposed on both the top and bottom faces of the insulating ceramic substrate (Fig. 4). Finally, the connecting terminals of the wiring lines are connected on both the top and bottom faces through holes (page 2, ¶ 23 and 26).

Notably, Aoyagi discloses a conventional linear transformer core. It does not disclose a toroidal transformer core where the ceramic toroidal core is integrally formed with the ceramic substrate. It also does not disclose a method for forming a transformer that has a ceramic toroidal core region integrally formed with the ceramic substrate. This point is significant because Aoyagi's technique could not be effectively applied to toroidal transformers since. Aoyagi suggests a bore can be machined transversely between the upper and lower layers forming the substrate so as to define a linear cavity. This approach is perhaps satisfactory for Aoyagi's simple linear core transformers. However, it would not be practical to transversely drill or machine a toroidal cavity beneath the surface of the substrate in the manner proposed by Aoyagi. Accordingly, it is not all apparent from a reading of Aoyagi, that it would be even possible to create a toroidal transformer where the ceramic toroidal core is integrally formed with the ceramic substrate.

In contrast, independent apparatus claims 1 recites a ceramic toroidal core integrally formed within a ceramic substrate. Aoyagi does not suggest such an embodiment. In fact, a fair reading of Aoyagi would suggest that the invention disclosed therein is only applicable to linear transformer cores. Aoyagi's drilling and machining process actually teaches away from a toroidal embodiment of the invention. Aoyagi teaches machining a transverse bore in the surface of a substrate to define a cavity. However, those skilled in the art will readily appreciate that it would not be practical to transversely machine a toroidal cavity within the thickness of the substrate material.

Applicant's claims 1 and 5 specifically recite a toroidal core as a limitation. This feature, in conjunction with the recitation of a toroidal core integrally formed with the substrate, clearly distinguishes the Aoyagi reference, which only teaches linear cores. Independent method claims 10 and 18, similarly recite a method for forming a transformer with a ceramic toroidal core integrally formed with the ceramic substrate. In contrast, Aoyagi only teaches a process for forming a transformer with a linear core.

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Aoyagi uses conventional machining techniques, i.e. transverse drilling or boring to form a cavity in the substrate. This is an important distinction, because it is not at all apparent how the machining in Aoyagi could be used to form a transformer with a toroidal core integrally formed with a substrate. Simply put, Aoyagi would not suggest a toroidal core arrangement to one of ordinary skill in the art.

In contrast, Applicant's claimed process permits the formation of a toroidal core integrally formed with the substrate. Moreover, Applicant's claimed process is advantageous in that LTCC structures can be constructed without altering conventional LTCC processing techniques. This is a significant departure from Aoyagi, which require that high permeability materials be inserted or backfilled in apertures that are machined in the substrate during the manufacturing process.

Harding fails to make up for the deficiencies of Aoyagi. Harding discloses methods of constructing inductive components, namely toroidal transformers (Harding, Abstract). The Harding reference includes a toroidal transformer core and a substrate, both made from ferromagnetic metal material (Fig. 3A; col. 2, lines 18-22; col. 5, lines 21-29). The transformer core is wound with copper wire to form a number of multiple turn windings (Fig. 3B; col. 2, lines 1-14).

Harding teaches numerous ways in which to embed the ferromagnetic metal core within the substrate. One method of fabrication can include embedding several ferromagnetic metal slabs between printed circuitry (col. 1, lines 64-66). Another method includes embedding several ferromagnetic metal pieces between the top and bottom layers of a printed circuit board (PCB) circuits (col. 4, lines 38-43). A panel is formed to accommodate each ferromagnetic metal core piece. Yet another method teaches that the core can be formed by a multi-layer series of thin concentric ferromagnetic metal rings supported on a flex circuit or PCB (col. 2, lines 18-22).

However, the Harding reference fails to teach that the core and substrate are of a ceramic material, as is recited by Applicants in amended independent claims 1, 10, and 18. Applicants' amended independent claim 1 recites a transformer embedded in an LTCC substrate comprising a ceramic substrate and a ceramic toroidal core embedded within the ceramic substrate. Applicants' amended independent claim 10 recites a method for forming a transformer in a ceramic substrate. Claim 10 further recites the

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step of forming at least one conductive coil of a plurality of turns about an unfired ceramic toroidal core region defined within an unfired ceramic substrate. Moreover, Applicants' amended independent claim 18 recites a method for forming a transformer in a ceramic substrate. Claim 18 further recites the step of forming a plurality of vias and traces in an unfired ceramic substrate to define at least one conductive coil of a plurality of turns about an unfired ceramic toroidal core region defined within an unfired ceramic substrate

Instead, Harding teaches in a first embodiment that both the core and substrate are made of a ferromagnetic metal material. (Harding, Abstract). In a second embodiment, Harding teaches that the core of the transformers comprises cores formed by a multi-layer series of thin con ferromagnetic metal rings supported on a suitable substrate such as a flex circuit or printed circuit board (col. 2, lines 18-22). Notably, Harding does not disclose a method for manufacturing a toroidal transformer in a ceramic substrate. According to Harding, "[c]opper circuit patterns 92 corresponding to the desired windings are formed on an [sic] epoxy sheets 110 which are glued to the top and bottom surfaces 112, 114 of the slab by adhesive 115. The cores 90 are thus contained in the circuits 92 by a lamination process." (Figs. 5-7; col. 4, lines 21-28). Via holes are formed through the composite FLEX layers and core.

The foregoing distinction is important. One skilled in the art would recognize that the epoxy sheet layers disclosed in Harding would not be suitable for creating a toroidal transformer in a ceramic material. In particular, the toroidal ferromagnetic core in Harding would not be compatible with the ceramic co-firing process as recited by Applicants' claim 10 and amended claim 18. Claims 10 and 18 both recite "co-firing said unfired ceramic toroidal core region, said unfired ceramic substrate, and said conductive coil to form an integral ceramic substrate structure with said conductive coil at least partially embedded therein." Harding does not show Applicants' ceramic toroidal core integrally formed with a ceramic substrate. Instead, Harding discloses various methods of backfilling the core with ferromagnetic metal material. (Harding, col. 4, lines 21-67). Mere backfilling of material in this way does not result in a core that is integrally formed with the substrate. For the core to be integrally formed with the

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substrate, both components must simultaneously undergo a co-firing process after the components are assembled together. This feature is not taught by Harding.

In contrast, claim 10 and amended claim 18 in the present application recite a process that avoids the need for the additional processing steps associated with the prior art. Rather than machining cavities/cores and inserting magnetic material, the present method forms entire layers of the substrate from ceramic material having a high permeability. These layers can be selectively arranged to intersect a core region of the toroidal transformer. The foregoing process can provide improved manufacturing efficiency as compared to conventional processes that require backfilling.

Aside from method claims 10 and 18, Applicants' apparatus claim 1 also recites that the "ceramic toroidal core is integrally formed with said ceramic substrate in a co-firing process." Similarly, Harding does not teach a ceramic toroidal core being integrally formed with a ceramic substrate in a co-firing process. In view of the foregoing arguments, Harding fails to disclose several important features of the Applicants' invention as recited in independent method claims 10 and 18, as well as apparatus claim 1.

In summary, while Harding and Aoyagi individually teach certain elements that are present in Applicants' invention, the references fail to teach the fact that the ceramic toroidal core is integrally formed with a ceramic substrate in a co-firing process. Therefore, Applicants request that the Examiner withdraw the rejection of claims 1, 10, and 18 under §103(a).

Dependent claims, 2, 8, 19, and 23 have been rejected under 35 U.S.C. §103(a). However, in view of the arguments presented earlier regarding independent claims 1, 10, and 18, Applicants believe that these dependent claims are in condition for allowance at least on the basis of their dependence upon an allowable base claim.

b. Claims 3, 9, 11, and 20

Dependent claims 3, 9, 11 and 20 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Aoyagi, in view of Harding as applied in claim 1 and further in view of U.S. Patent No. 5,029,043 to Kitahara et al ("Kitahara, et al"). However, in view of the arguments presented earlier in section a. regarding independent claims 1,

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10, and 18, Applicants believe that these dependent claims are in condition for allowance at least on the basis of their dependence upon an allowable base claim.

c. Claims 4, 5, 12, 13, 21 and 22

Claims 4, 5, 12, 13, 21 and 22 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Aoyagi, in view of Harding as applied in claim 1 and further in view of U.S. Patent No. 6,847,282 to Gomez et al. ("Gomez, et al."). Gomez et al. discloses a multiple layer inductor having first and second spiral conductive patterns disposed on first and second surfaces, respectively. A continuing interconnection is coupled to the first and second spiral conductive patterns. An interface is coupled to the first and second spiral conductive patterns. A conductive bottom shield pattern having a voltage potential, such as ground, is disposed on a third surface that is adjacent to the second surface. The interface includes a first terminal disposed on the first surface that is coupled to the first spiral conductive pattern. The interface also includes a second terminal that is disposed on the first surface and coupled to the second spiral conductive pattern. Printed ground planes provide shielding to the first and second spiral conductive patterns. The ground planes are connected by vias that penetrate the substrate.

While Gomez teaches the use of a conductive ground plane layer disposed within a substrate, Gomez fails to make up for the deficiencies found in both Harding and Aoyagi. Independent claims 5, 13, and 22 contain respectively the same limitations as independent claims 1, 10, and 18, except for the additional claim language pertaining to either the presence or disposition of a conductive ground plane layer. As with the Harding and Aoyagi references, Gomez also fails to show a ceramic toroidal core that is integrally formed with a ceramic substrate in a co-firing process. In fact, Gomez et al. does not teach a method of forming the multiple layer inductor. Therefore, Applicants request that the Examiner withdraw the rejection of claims 5, 13, and 22 under §103(a). Dependent claims 4, 12, and 21 are believed to be in condition for allowance at least on the basis of their dependence upon an allowable base claim.

d. Claims 6, 7, 14-16, and 23-25

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Claims 6, 7, 14-16 and 23-25 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Aoyagi, in view of Harding as applied in claim 1 and further in view of U.S. Patent No. 6,148,500 to Krone ("Krone"). However, in view of the arguments presented earlier in section a. regarding independent claims 1, 10, and 18, Applicants believe that these dependent claims are in condition for allowance at least on the basis of their dependence upon an allowable base claim.

e. Claims 17 and 26

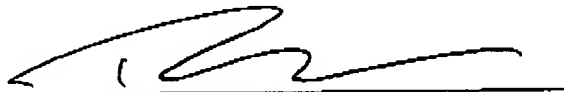
Claims 17 and 26 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Aoyagi, in view of Harding as applied in claim 10 and further in view of U.S. Patent No. 4,626,816 to Blumkin, et al ("Blumkin et al"). However, in view of the arguments presented earlier in section a. regarding independent claim 10 and 18, Applicants believe that these dependent claims are in condition for allowance at least on the basis of their dependence upon an allowable base claim.

III. Conclusion

Applicants have made every effort to present claims which distinguish over the prior art, and it is believed that all claims are in condition for allowance. Nevertheless, Applicants invite the Examiner to call the undersigned if it is believed that a telephonic interview would expedite the prosecution of the application to an allowance. In view of the foregoing remarks, Applicants respectfully request reconsideration and prompt allowance of the pending claims.

Respectfully submitted,

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